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Abstract

Many Edinburgh medical students will be familiar with the set of computer assisted learning programs (CALs) called PathCAL, which help the user understand the basic pathological principles of disease. Currently we have approximately 110 programs running on the Web, available to anyone with access to the Edinburgh Electronic Medical Curriculum (EEMeC). These programs did not spring into being overnight: their gestation was long and frustrating. I am taking up the offer to relate it, although I am acutely aware that writing about the history o f anything from personal experience is a real sign of advancing years.

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Many Edinburgh medical students will be familiar with the set of computer-assisted learning programs (CALs) called PathCAL, which help the user understand the basic pathological principles of disease. Currently we have approximately 110 programs running on the Web, available to anyone with access to the Edinburgh Electronic Medical Curriculum (EEMeC). These programs did not spring into being overnight: their gestation was long and frustrating. I am taking up the offer to relate it, although I am acutely aware that writing about the history of anything from personal experience is a real sign of advancing years.

So how did the system emerge? We have to go back a long time. In 1983, I took up a post as lecturer in pathology in the University of Leeds. The head of department was then Professor Colin Bird, later Dean in Edinburgh. He was keen on modern technology and had recruited a trainee pathologist, Pat Harkin, who had a strong computing interest. Around this time Pat devised a program that would allow academics with limited technical expertise to write scripts for computer-assisted learning programs directly on to computer. These programs would run on a BBC computer, which was then the state of the art model. A number of trainee and consultant pathologists were delegated to write scripts for interactive tutorials on various topics. Despite the intention, however, few staff members developed the small amount of expertise necessary and in practice Pat inserted the material for them. The idea of the programs was to allow students to work though text and questions on a topic in pathology, related at suitable points to macroscopic and microscopic pictures of diseased tissue. At that time computers were much more primitive than now and it was not technically possible to put the images on the computer screen. They were instead accessed in photograph albums and students were directed to "look at picture A5". These were replaced by computer-controlled microfiche projectors and later we advanced to computer-controlled slide viewers, there being a separate one for each computer. There were about 12 terminals, located in the Pathology Department museum, and these ran on a small network with a hard drive in a nearby cupboard. The system was pretty clunky, but we were very proud of it. We were struck by its popularity with students, no doubt partly due to its novelty. Professor Bird was at all times encouraging and enthusiastic and played a full part in dragging off hapless visitors from other universities to see the system in action. At one point he even floated the idea of ditching our other teaching methods, but after some discussion we decided that this would be too radical.

In 1986 Professor Bird moved to Edinburgh as professor of pathology and engaged Pat Harkin to set up a set of computer-assisted learning programs similar to those in Leeds. This parallel set ran in Edinburgh for some years.

By the early 1990s computing technology had moved on. The BBC computer was becoming effete and the slide carousels gradually stopped working. Servicing the network became progressively more difficult and eventually the hard drive crashed. With some skill, Pat rescued the data and printed the text of the programs before the system finally expired.

At this time, at the request of the Wellcome Trust, Pat devised a new program called video-active program author (VIPA) that allowed a non-expert to insert questions and text into a set of templates. VIPA ran on IBM PC hardware but was written before Microsoft Windows became popular. Nevertheless it was the first time that it became possible to put the images on the same screen as the text. This gave us the opportunity to create a new version of our programs in Leeds. Originally the intention was to transcribe the text of the old ones, but, when we reviewed the printed versions of these, we realised that they had limitations. They did not fully exploit the potential interactivity that is one advantage of a computer-based system. As the programs had been written by different individuals, they differed markedly in style, which in some cases was rather heavy and academic. Many of the slides used as pictures were of poor quality. Much of the microscopy was of archaic tissue from ancient student histology class boxes. We eventually decided to write a new set of programs from scratch. I undertook to do this, as we reckoned that it was probably easier to have a uniform style and have others criticise the content than to have different people write them and then edit the text. At this time I acquired a new computer, a PC, which greatly expanded the possibilities. In 1993-94 I wrote about 70 tutorials, typing the text directly on to computer. This was nearly all done outside normal working hours.

During this time digitised images become more readily available and it was possible to incorporate these into the programs, rather than on separate machines. I took a lot of new images, using specially prepared high-quality material from the diagnostic pathology service, to replace the old ones. We included preparations by techniques such as immunohistochemistry and oil-immersion microscopy of specially cut thin microscope sections showing cell organelles. Cameras and microscopes were also of high quality. We took films and projection slides to the local chemist's shop, where they were digitised and given back to us on compact discs (CDs). On one occasion they gave me in error someone's family snapshots, but I never discovered whether the possessor concerned was in turn presented with a CD of tumours. The draft scripts were printed and passed round the critical eyes of sundry colleagues for amendment. So gradually a lot of individuals had an input into their content and their names are still present at the beginning of each CAL program.

We ran our CAL packages on a small network of 12, located as before in the Pathology Department museum. By this time, however, the computer network of the whole university was becoming more sophisticated and we felt that if we could run the system on it we could increase access dramatically. Unfortunately the VIPA system turned out not to be compatible with the university network. A short spell of despair followed, as the prospect of much wasted effort loomed. Fortunately, Pat had a contact, Kim Whittlestone, then in Bristol, who had devised a set of templates that ran on the package Asymmetrix Toolbook, which could be made to run on our university network. With some effort Pat wrote a program that would import our cherished VIPA tutorials into Toolbook. We were thus able to get our programs to run on the network in Leeds. As it happened, we also organised the undergraduate courses for medical and dental students and were able to direct the attention of large numbers of students to the programs, as part of their resource material.

In 1996 I decided on a career shift and moved to Edinburgh, where Professor Bird had become Dean of the Medical School and the academic head of the Pathology Department was Professor Andrew Wyllie. I found that the computer-assisted learning system Professor Bird had transposed in 1986 had by then moved on, but in a slightly different direction from that in Leeds. In Edinburgh, a set of programs was running on the University network but had been written in the package Authorware. This demanded the wizardry of a computer programmer and he had unfortunately left, so that nobody was available to continue the work. With advice from Andrew Short and Gill McConnell in Veterinary Medicine I tried to learn Authorware, but without success. With Pat Harkin's considerable aid I got the Toolbook CAL programs set up in Edinburgh and, with the help

of Susan Wexler, who had responsibility for the computing network in Medicine, we were able install the programs. As Authorware and Toolbook were mutually incompatible we had to run the two systems separately. Fortunately I became proficient in Toolbook and was able to write more programs with the templates. Mark Arends in Pathology also learned to use Toolbook and wrote some tutorials on genetics.

By this time I realised that, in developing any learning technology, the use of well-recognised principles of learning psychology could readily enhance the student's learning. Chunking, for example, is the technique of breaking material into small, easily digested units, rather than having great screenfuls of closely-packed text. Rehearsal is the process of reiterating the material, often in slightly different format. For example, information can be presented as free text questions and then later as multiple choice questions. Vivid imagery, with graphics, animations and video material, is also likely to be remembered. Dual encoding is when information is presented in more than one format, for example visually and by sound. We have not so far exploited this, partly because having sound on programs in a computer cluster would cause disturbance, although this could be overcome with headphones. These are well-researched principles and facilitate the encoding of information into short and long term memory. I attended a few of the honours psychology classes run by Hamish MacLeod and Charles Anderson. The medical school's educational experts, Gordon Watson and Phillip Evans, became interested in the psychology aspect of computer-assisted learning and we conducted some studies in this field. An essential overall aim of all this is to promote a deep approach, rather than a surface approach to learning and the extent to which the programs can do this would be an interesting research project.

At this time the programs were used mainly by Years 2 and 3 students studying pathology. We undertook evaluation questionnaires and found that the popularity of the computer-assisted learning programs among students was high. Professor Andrew Wyllie was also keen on computer-assisted learning, as were other colleagues, including Raashid Luqmani, of Rheumatology, and Mark Arends, Andrew Krajewski Alistair Williams and others in Pathology. We set up a CALs group, which met regularly to plan further development.

By 1998 it was becoming clear that the future lay in making the system Web-compatible. Unfortunately neither Toolbook nor Authorware at that time existed in versions that would run on the Web. Raashid Luqmani spent much time writing programs that might transfer the CALs to the Web, but the technicalities of the University computing networks would not allow them to run. Andrew Krajewski, too, devised templates in FrontPage and we did some work on this, but again the University network beat us. As technology progressed, the network ceased to support Authorware and we had to ensure that its contents were replicated in the Toolbook CAL programs. We were, however, fortunate that David Dewhurst arrived in Edinburgh from Leeds and developed the Learning Technology Section (LTS). As this expanded, various individuals, notably Rachel Ellaway, Peter Douglas, Jake Broadhurst and Steve Fox became involved. With the development of the Edinburgh Electronic Medical Curriculum (EEMeC), it finally became possible to make the programs run on the Web. Stewart Cromar in LTS started this, but transferring the existing programs entailed laboriously copying and pasting all their components individually and was obviously going to be a big job. Professor David Harrison, in Pathology, obtained financial support and in 2001 this enabled Jackie Aim in LTS to start transferring the programs to Web-compatible format. We took the opportunity to update the content of the programs and this work was completed in 2004. They are currently available to students in Edinburgh and are also supplied to medical students in Cambridge, where Mark Arends and Kim Whittlestone have both moved and take an interest in their use. At some point I was asked to come up with a name for the pathology programs and invented the name PathCAL, for want of any better suggestion. As it widens to include other branches of clinical medicine, it needs changed, but other obvious names are already in use.

So what advantage does computer-assisted learning have over learning by other methods? Consider a textbook. Now, there has undoubtedly been a great advance over the years in the standard of textbooks. Modern textbooks present information beautifully, with fine coloured diagrams and photographs. There are, however, certain limitations. Many are fine academic works and the text tends to be written in a relatively turgid, concise style. This is splendid as scholarship, but the evidence from psychology suggests that it may not facilitate learning, especially by a beginner. There is also a serious limitation of space. The rather static pictures in a textbook, especially those of diseased organs, are often poorly annotated for the beginner. Pictures of microscopy are particularly difficult for those inexperienced in the pattern recognition skills that come only with much practice. In a computer package it is easy to delineate components with flashing outlines and to indicate different components in separate images. It is also easy, with computers, to reiterate information by building up diagrams step by step. Mind maps can also be built up in steps in a way that would be repetitious in a book, where conservation of space is a major factor. We can readily recapitulate information from other realms of knowledge. Thus, for example, in a discussion on renal or thyroid disease, we can reiterate material from immunology and thus seek to prevent the student from forgetting material previously learnt. More recently, we have incorporated animations and movie images, to show molecules moving together and interacting in easy stages, which is clearly not feasible in a book. The programs on cell signalling demonstrate the potential in this area. It is important to use these as genuine learning adjuncts and not just as gimmicks. They are time-consuming to do, but slowly we are incorporating them into programs.

Perhaps the most important aspect for learning is interactivity. A book can pose questions and give the answers, but in a computer program the user is forced to think and insert answers before s/he is able to continue. This interactivity is a very powerful way of promoting learning. By being forced to answer questions, the user cannot simply assume that s/he knows the material, as is the case when reading a textbook, and cannot fail to learn, especially if the questions are posed in different form later. In technical terms, of course, the computer recognises not the answer as such, but a string. It can thus be tailored to suit, for example, American spelling, or different synonymous answers. There is clearly a knack in devising and anticipating these. Although this interactivity is not explicit in a book, an experienced learner will interact with the material. In certain tutorials we give guidance on this and thus exploit the computer's potential in assisting learning by other modalities.

Then there is the question of keeping the material up-to-date. Any textbook will be out of date as soon as it is in the shops. A computer package, by contrast, can be updated regularly. Many of the improvements in the programs came from comments by students over the years and some students' names feature as editors or commentators. At present we do not have the staff to keep the programs as up-to-date as we would like, but hopefully in the future it will become possible. Computers also cater for distribution. A student can use it anywhere in the world with access to the Web. At present an Edinburgh medical student can gain access to the PathCAL on elective in the Far East or even on holiday on a Greek island, despite the risk of drenching the keyboard in ouzo.

More specifically, the PathCAL programs we have in Edinburgh aim to guide users on how to approach the study of pathology and medicine, apply general pathological principles to body systems and recognise certain abnormalities. This is done by explaining new terms and then forcing the student to use them to answer questions. The programs consistently give students feedback on their own knowledge and understanding and develop their ability to reason through disease-related problems. The programs can be used by beginners for primary learning or by more experienced students for self-assessment. Although the full set of tutorials is currently in use mainly by students of medicine, some would also be suitable for students of dental surgery, veterinary medicine, biology, nursing, paramedical specialities and for those studying for postgraduate examinations in surgical and medical specialities. As part of a study, Gordon Watson watched students at work and occasionally probed them. He was interested to note that beginners found the programs helped them understand and use correct terminology. This is part of the development of professional expertise, the so-called novice-expert shift.

The different question styles used in the programs have specific roles. For example, in the free response question, the student is invited to enter a short answer and the computer responds, often with embellishments.

There are also multiple choice questions comprising a stem and several items, each of which is either true or false: The student selects the answers and then follows the answers, with an explanation of why each correct answer is correct and why each wrong answer is wrong. The answers can be revealed after the student has answered each item either one at a time or as a group of five. The true-false format is now somewhat out of favour in summative examinations, but is still useful for promoting learning by formative testing. A further style of question is the modified essay in which the student enters a more detailed, discursive, answer. The computer then reveals a model answer and the student compares the two and awards him/herself a mark. This style of question allows deeper understanding to be tested. In constructing a tutorial, it is useful to progress towards these modified essays in the later stages, so that the student recaps on previous material. At the end of the tutorial the user gets a score; so self-deception is discouraged.

In updating the programs, the link to Email (*PathCAL@ed.ac.uk*) is very useful. Many students send comments and criticisms directly. In some cases these are to point out mistakes and in other cases they feel that something is not clear. Gradually the programs have been amended to incorporate these suggestions and in some cases the name of the student concerned has been included as a "user editor".

With the transfer of the Cal programs to the Web, it has become possible to include other devices. Video material, for example, can be streamed and added. We have a good deal of video material of real specimens, taken at autopsy or from surgically resected tissue. Pathologists now take images in digitised form, often as part of the report on a specimen, and we thus have enlarging banks of images at the ready. Some of this is on a searchable image database. As much diagnostic imaging in hospitals has now become digitised, it will in the future be easy to obtain material such as X-ray images, angiography, CT and MRI scanning images, all of which lend themselves well to incorporation into Cal programs. So the learning possibilities are enormous.
Recently, the Edinburgh Reusable Objects Sequencer (EROS) has been developed. This allows designated individuals to write programs directly on the Web. Other computer-assisted learning programs, such as George, the respiratory patient developed by Pat Warren, and Hannah, the pregnant woman, are also now developed using this system. This is clearly a great advance, although it does illustrate one difficulty, namely keeping abreast of changing technology. The whole system on which the PathCAL programs run is now in its fourth generation and each time the components have had to be copied across. The computer packages for constructing diagrams and photographic equipment for taking images change with breathtaking speed.

At various points over the years we have undertaken evaluation studies and these regularly show a high degree of student satisfaction with the computer-assisted learning programs in Edinburgh. They regularly turn out to be the most popular learning method in the Year 2 medical course. This is very encouraging and gives grounds to be optimistic about their future.

The PathCAL system also now records the answers students put to the questions. This is known as tracking. We can call up a list of all the answers users have inserted to every question in every CAL program. This is anonymous in that we cannot trace the user, but it allows us to see how questions perform. If certain correct answers are being rejected, we can amend the answer required. If users regularly insert certain wrong answers, this suggests that there are consistent misunderstandings and we can amend programs, or alter other aspects of teaching, to pre-empt these. Potentially, this could link to computer-assisted assessment, in which students take examinations on computer, but we have not yet developed this in relation to PathCAL in Edinburgh.

So what of the future? Almost from the inception of the programs we have aimed ultimately to make them available to students more widely than in one medical school. This requires certain technical features, namely a dedicated server, so that when large numbers of outside users log on, the computing network in Edinburgh does not crash. We are currently attempting to acquire financial support for this. The intention at present is that medical schools and other institutions would subscribe a nominal sum to allow their students to gain access to the programs. It is also a requirement that users log on, as the university must keep track of individuals who are interacting with, rather than merely looking at, material on its servers. This would clearly require some supportive technical infrastructure.

To keep the programs up-to-date we would in due course need a team of writers. It is obviously important to imagine how a beginner would use a program and address the issues that s/he might find difficult. Part of PathCAL's appeal is that the writing style is informal and even chatty. Many academics do not find it easy to write as they would speak; it is entirely different from the formal style we learn to use in writing scientific papers. Personally, I find it fun and intellectually taxing in its own way. Having a juvenile sense of humour may also be an asset. We can now give several individuals on-line authoring rights to the one tutorial. An advantage is that it can be done anywhere with Internet access, although I wait in vain for paid leave of absence in an alpine ski resort to write more material. A system for dealing with Email correspondence would also be desirable. There are also legal considerations in expanding the system. A further development would be to construct so-called intelligent tutorials. These would change in response to user needs, so that someone who gave correct answers to test questions could move into different, more difficult areas during a program. There is further educational research work to be done exploring the use of tutorials in expanding student learning.

Will computer-assisted learning replace books and other learning methods? I do not think so. There is still something pleasant about learning by sitting with a book in front of you. Also, it is important to be able to learn from the formal prose of a textbook: translating this into useful knowledge is, in its own way, all part of the learning process. Participating in a tutorial is also a perfectly legitimate way of enhancing one's learning. Furthermore, some people just do not like computers and there is nothing wrong with that. So books, tutorials and other learning methods will still be with us. But computer-assisted learning, too, has its place and is here to stay.

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